Evaluation of fate and transport of macro- and micro-plastics in terrestrial-aquatic continuum of entire Japan by developing a spatio-temporally explicit eco-hydrology model

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Contamination of plastic materials in our environment has received more attention from the public, scientists, and policy makers during the last few decades. Though some of the models have succeeded to simulate the transport and fate of plastic debris in freshwater systems, a complete model is under development to elucidate the whole picture of plastic dynamics in the basin scale. One of the authors has so far developed a process-based eco-hydrology model, NICE (National Integrated Catchment-based Eco-hydrology) (Nakayama and Watanabe, 2004) and NICE-BGC (BioGeochemical Cycle) (Nakayama, 2017), and applied them to various basins from local/regional to continental/global scales. NICE-BGC can simulate iteratively nonlinear interactions between hydrologic, geomorphic, and ecological processes (water, heat, sediment, nutrient, and carbon cycles, etc.) (Nakayama, 2020). In this study, the authors extended NICE-BGC to couple with plastic debris model for freshwater systems, and applied it to all the first-class river basins in entire Japan (109 river basins). The new model included the advection, dispersion, diffusion, settling, dissolution and deterioration due to light and temperature, but assumed no interaction with suspended matter (heteroaggregation), resuspension, biofouling, and effect of wind, etc. The authors also assumed plastics as pure and totally inert polymers and spherical particles with constant size and density for model simplification. NICE-BGC simulated how mismanaged plastic waste (MPW) of about 36,000 ton/yr (Meijer et al., 2021) and point sources such as tyres, personal care products (PCPs), dust, and laundry in the entire country are transported from land to river, and finally to the ocean. The model showed the total flux of macro- and micro-plastics varies dependent on the removal efficiency of micro-plastic in wastewater treatment plants and the density of plastic. It was clear that only limited plastics discharged to land flows out into the ocean intensively during rainfall seasons, similar to plastic loading estimates in the previous study (Nihei et al., 2020). These results help to quantify the impacts of plastic waste on terrestrial and aquatic ecosystems, and find solutions and measures to reduce plastic input to the ocean.